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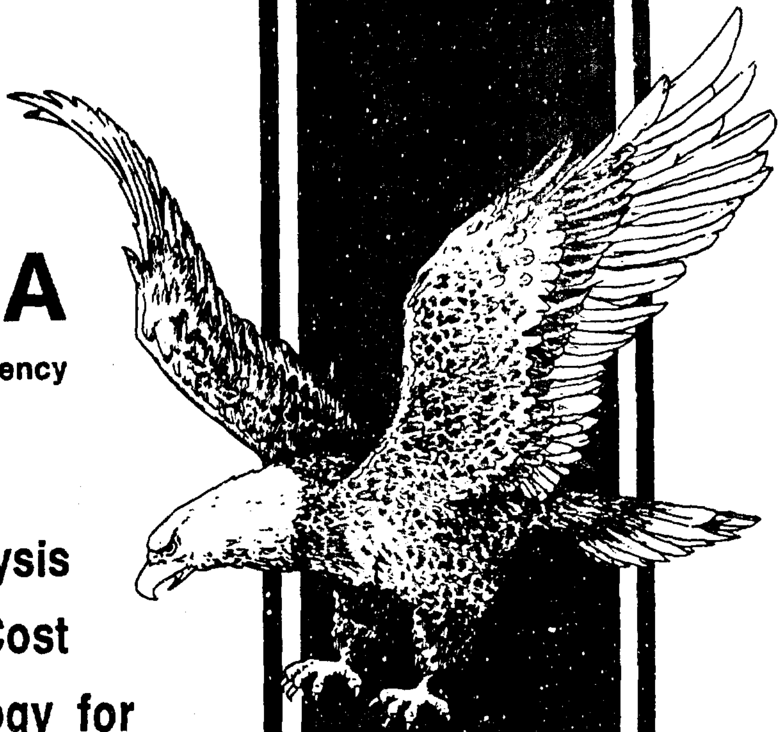

USATHAMA

U.S. Army Toxic and Hazardous Materials Agency

Economic Feasibility Analysis for Development of Low-Cost Chemical Treatment Technology for Explosive Contaminated Soils

CONTRACT NO. TV-74541A
USATHAMA REFERENCE CETHA-TE-CR-90053

TENNESSEE VALLEY AUTHORITY

NATIONAL FERTILIZER & ENVIRONMENTAL RESEARCH CENTER

MAY 1990

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An evaluation of seven theoretical chemical treatment process options, as potential methods of decontaminating explosives-contaminated soil at a variety of remediation sites, was undertaken by the Tennessee Valley Authority (TVA) for the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA). The chemical treatment process options evaluated included:

- Caustic Hydrolysis/Peroxide Oxidation (evaluated in two plant-scale sizes: (1) skid mounted portable, and (2) transportable after disassembly).
- Shock Plasma.
- Microwave/Hydrolysis/Oxidation.
- Microwave/Sonic/Hydrolysis/Oxidation.
- Nitric Acid/Heat.
- Supercritical Fluids.

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The evaluation focused on economics but also addressed the feasibility and technical uses that would be associated with developing the process options for full-scale operation.

ECONOMIC FEASIBILITY ANALYSIS

FOR

DEVELOPMENT OF LOW-COST CHEMICAL

TREATMENT TECHNOLOGY FOR EXPLOSIVE CONTAMINATED SOILS

FOR

USATHAMA

CONTRACT NO. TV-74541A

USATHAMA REFERENCE CETHA-TE-CR-90053

APRIL 1990

Tennessee Valley Authority
National Fertilizer & Environmental Research Center
Muscle Shoals, Alabama 35660-1010

TABLE OF CONTENTS

I. SUMMARY

An evaluation of seven theoretical chemical treatment process options, as potential methods of decontaminating explosives contaminated soil at a variety of remediation sites, was undertaken by the Tennessee Valley Authority (TVA) for the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA). The chemical treatment process options evaluated included:

- Caustic Hydrolysis/Peroxide Oxidation (evaluated in two plant-scale sizes: (1) skid mounted portable, and (2) transportable after disassembly).
- Shock Plasma.
- Microwave/Hydrolysis/Oxidation.
- Microwave/Sonic/Hydrolysis/Oxidation.
- Nitric Acid/Heat.
- Supercritical Fluids.

The evaluation focused on economics but also addressed the feasibility and technical uses that would be associated with developing the process options for full-scale operation.

The most desirable option was the use of caustic hydrolysis/peroxide oxidation. This option had lower operating and capital costs when compared to the other process options evaluated.

Of the remaining chemical treatment process options evaluated, microwave/sonic/hydrolysis/oxidation and nitric acid/heat processes were found to be technically infeasible; shock plasma is a process currently being developed by a private company and, therefore, it was not possible to obtain a cost estimate; and microwave/hydrolysis/oxidation and supercritical fluids processes

were very costly when compared to the caustic hydrolysis/peroxide oxidation process.

Although the caustic hydrolysis/peroxide oxidation process proved to be a desirable option and capital and operating costs were significantly lower than that of the other chemical treatment process options evaluated, it is not significantly lower in cost than composting, a biotreatment process, currently being evaluated by USATHAMA.

II. INTRODUCTION

The United States Toxic and Hazardous Materials Agency (USATHAMA) has contracted with the Tennessee Valley Authority (TVA) to examine the possibility of using chemical treatment as a method of decontaminating explosives-contaminated soil. Presently, USATHAMA is studying incineration technology and composting technology in demonstration facilities as methods of decontamination. Composting is the least expensive of these two technologies and is targeted at $100 per ton of soil when fully developed for large scale use. If it could be shown that there is any potential for some type of chemical treatment being significantly less costly than composting (e.g., $40-50 per ton), then USATHAMA would initiate actual experimental efforts to develop that treatment technology, realizing it to be a high risk venture.

Chemical treatment is a broad term that is basically described as any process in which organic waste is broken down into innocuous components by the action of chemical additives under controlled process conditions. Chemical treatment can take many forms but the most widely used technique is chemical oxidation. Oxidation converts most forms of organic matter into innocuous substances, primarily carbon dioxide and water.

This study seeks to determine the economic feasibility of decontaminating explosives-contaminated soil using a chemical treatment process which can be moved from site to site. Operating and capital costs are examined for one portable process (skid mounted on a flat bed truck trailer) and six different transportable processes (can be disassembled and transported to the remediation site for reassembly). The processes are theoretical in nature. Simplifying assumptions are used in the design of each process so as to minimize the cost and thus reflect the economic potential of each process. Three methods of removing the soil from the remediation site and transporting it to the chemical treatment process are also evaluated.

III. CHEMICAL TREATMENT TECHNOLOGY - PORTABLE PLANT DESIGN

3.1 Process Selection

There are many different chemical treatment processes that could be envisioned as potential methods for destroying explosives in contaminated soil. To meet objectives set by USATHAMA, the process must be relatively inexpensive compared to currently-used methods of incineration and composting. The process should also be portable to allow cleanup at a variety of sites. For purposes of this study, portable is defined as a process that is fully assembled on one or more flat bed truck trailers, and is transportable over most state and U.S. highways with appropriate permits and escorts. The maximum allowable trailer width is 14 feet and the maximum height of the equipment is 17 feet from the ground.

One candidate process that was considered was "Aqueous Thermal Decomposition" (ATD). In a January 1985 lab research report (Report No. AMXTH-TE-CR-84309, Contract DAAK11-81-C-0076), ATD was proposed by the Army contractor, the Environmental Science and Engineering Company (ESE). The process is based on laboratory-scale work showing that explosive materials in contaminated soil can be decomposed in the liquid phase using high temperature (250°C) and pressure. A major drawback to the process is that decomposition is incomplete. The decomposition products are not explosive but they represent a hazard to the environment. Some form of additional treatment will be required to remove and/or further decompose these products.

Rather than modifying ATD with additional chemical treatment equipment, the objective of this economic evaluation is met in a more direct manner by proposing a simple chemical treatment process utilizing chemical oxidation.

The process that was selected for the conceptual design is a two-stage hypothetical process. The first stage uses caustic to hydrolyze the explosive in the soil and begin the explosive decomposition. The second stage uses hydrogen peroxide to oxidize the carbon and hydrogen elements in the explosive material. The caustic also enhances the action of the hydrogen peroxide.

This process design was made as simple as possible in order to seek a low cost. The intention is to show the potential minimum cost of chemical treatment technologies as an alternative to incineration or composting. The chosen chemicals (caustic and hydrogen peroxide) are among the least expensive of their respective types. No high pressure vessels are required. Fiberglass tanks are used wherever possible to lower costs.

The plant processing capacity was designed to be 2.4 tons per hour of contaminated soil, based on the constraints of the truck trailer size. The average throughput over time is estimated to be 2 tons per hour (83% on-stream factor). A process diagram for the portable process is shown in Figure 3.1. A material balance is given in Table 3.1.

Process Description. Explosive contaminated lagoon soil is delivered by front end loader to one of three identical slurrying tanks (V-1 A, B, C). Each slurrying tank is equipped with an overhead grizzly screen to remove stones and other oversize material. Recycle water from the process is applied to the grizzly screen using spray nozzles to break up chunks and slurry the soil. Makeup water is added to produce a slurry containing about 10-percent solids. The purpose of having three slurry tanks is to provide sufficient holding time (about one hour each) to analyze the explosives content of each batch. This will ensure that the proper chemical addition rate is used later in the process, and it will aid in achieving decontamination at minimum cost.

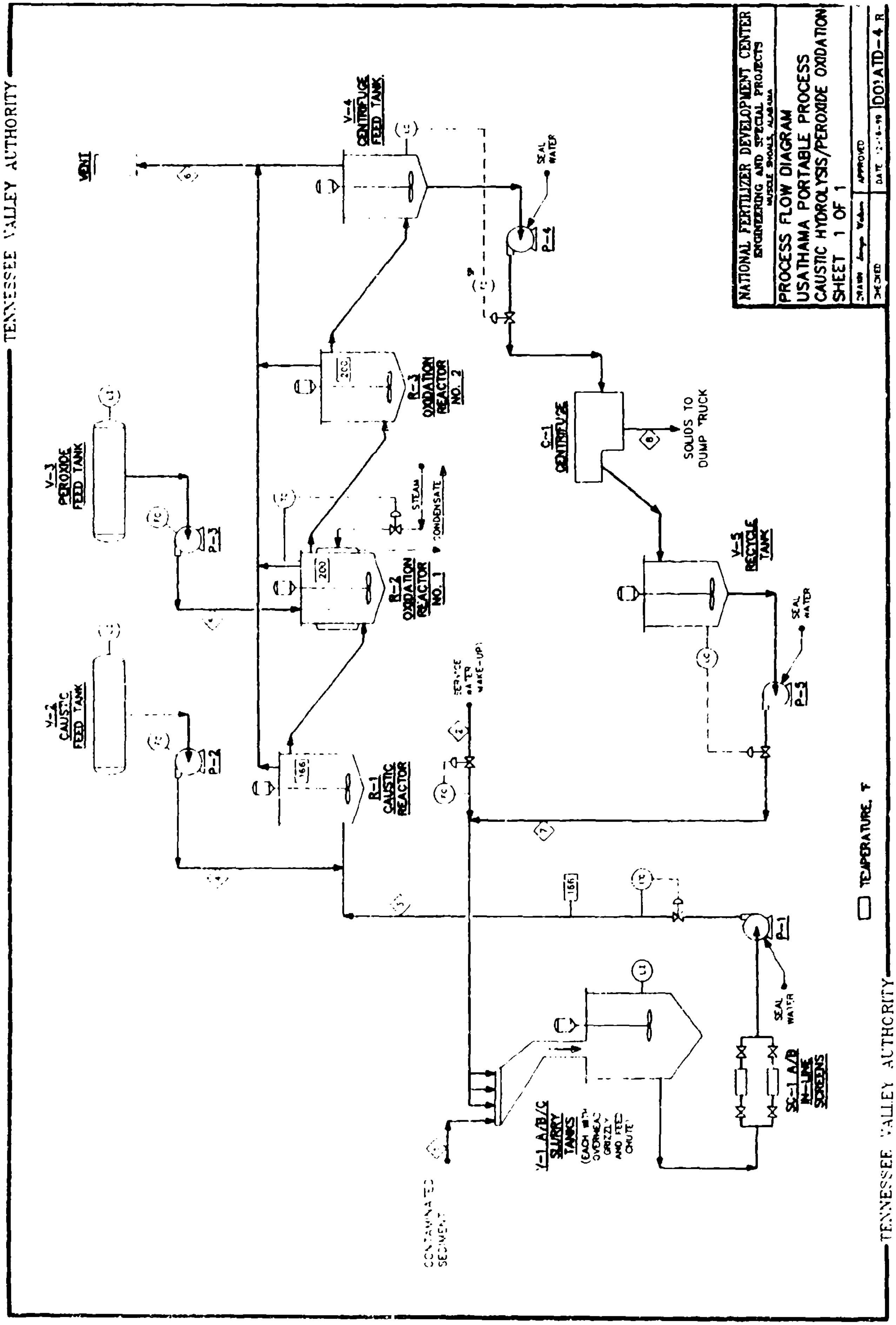

TENNESSEE VALLEY AUTHORITY
NATIONAL FERTILIZER DEVELOPMENT CENTER
ENGINEERING AND SPECIAL PROJECTS
MUSCLE SHOALS, ALABAMA
PROCESS FLOW DIAGRAM
USATHAMA PORTABLE PROCESS
CAUSTIC HYDROLYSIS/PEROXIDE OXIDATION
SHEET 1 OF 1
D01ATD-4 R
VENT
V-4 CENTRIFUGE FEED TANK
SEAL WATER
P-4
R-3 OXIDATION REACTOR NO. 2
V-3 PEROXIDE FEED TANK
P-3
STEAM
CONDENSATE
R-2 OXIDATION REACTOR NO. 1
C-1 CENTRIFUGE
SOLIDS TO DUMP TRUCK
V-5 RECYCLE TANK
V-2 CAUSTIC FEED TANK
P-2
R-1 CAUSTIC REACTOR
SERVICE WATER MAKE-UP
P-5
TEMPERATURE, °F
P-1
V-1 A/B/C SLURRY TANKS (EACH WITH OVERHEAD GRIZZLY AND FEED CHUTE)
SC-1 A/B IN-LINE SCREENS
CONTAMINATED SEDIMENT

Figure 3.1

Table 3.1

USATHAMA PORTABLE PROCESS - CAUSTIC HYDROLYSIS/PEROXIDE OXIDATION
MATERIAL BALANCE

Stream No.	1	2	3	4	5	6	7	8
Description	Soil Feed	Makeup Water	Slurry Feed	Caustic Feed	Peroxide Feed	Vent Gases	Recycle Water	Recovered Soil
Component	Flow Rate, Pounds Per Hour							
H_2O	1006	1975	33176	24	40	172	30108	3701
Solids	3701	-	3849	-	-	-	148	3701
TNT	38	-	38	-	-	-	-	-
NaOH	-	-	-	24	-	-	-	-
Na_2CO_3	-	-	40	-	-	-	40	5
$NaNO_3$	-	-	336	-	-	-	336	42
H_2O_2	-	-	-	-	94	-	-	-
CO_2	-	-	-	-	-	48	-	-
TOTAL	4745	1975	37439	48	134	220	30632	7449

The soil slurry is first pumped to the caustic reactor (R-1). Here the explosives are hydrolyzed (i.e., nitrate groups are removed from the TNT molecular structure) by addition of 50-percent caustic to begin the decomposition. The caustic reactor is equipped with agitation to maintain slurry conditions and has a residence time of 30 minutes. The caustic reactor overflows to the first of two agitated oxidation reactors (R-2 and R-3) arranged in series. Each reactor provides 30 minutes residence time. Hydrogen peroxide (H_2O_2) was selected as the oxidant because it is inexpensive compared to other chemical oxidizers and because, after reacting, only water remains as residue. All of the hydrogen peroxide is added in the first reactor. Steam is applied to the jacket of the first reactor to raise the reaction temperature to 200°F to enhance the reaction rate. During oxidation, the carbon in the explosive materials is converted to carbon dioxide and the hydrogen is converted to water. Some carbon dioxide remains in solution as sodium carbonate and the remainder escapes through the reactor vent system. Nitrogen from the explosive remains in solution as sodium nitrate.

After passing through the second oxidation reactor, the soil is now decontaminated and ready to be removed from the system. The decontaminated soil slurry is pumped to a continuous centrifuge which removes the soil as a cake containing 50-percent solids. The moisture in the cake is considered to be sufficient in quantity to purge the system of dissolved salts, thus preventing a buildup of sodium in the water circulation loop. The filtrate from the centrifuge is recycled to the slurry tank (V-1 A, B, or C) to complete the circulation loop.

Process Assumptions. Because this process is theoretical in nature, certain assumptions had to be made in order to assemble a complete design. These assumptions are listed below.

1. The average explosives content of the soil to be treated is 0.8 percent TNT. This is the average content of soil found at a remediation site at Cornhusker AAP. This is a key assumption because the quantity of chemical reactants (and their costs) will increase or decrease proportionately with the explosives content of the soil.

2. The addition rate of caustic to the hydrolysis reactor will be 20 percent in excess of the stoichiometric requirement and the reactor will require a 30-minute residence time. The excess caustic reacts with carbon dioxide in the oxidation reactors to form sodium carbonate.

3. The addition rate of hydrogen peroxide will be equal to the stoichiometric requirement and the reactor will require a 60-minute residence time. This is perhaps the weakest assumption because, generally, an excess over stoichiometric is required to drive a reaction to completion. Also, organic matter in the soil is expected to compete with the explosives for oxidant. However, naturally-occurring dissolved oxygen in the slurry is expected to contribute to a portion of the oxidation and thus make up any deficiency in peroxide.

4. An elevated temperature will be required to make the oxidation reaction proceed. A temperature of 200°F was selected as a practical temperature that could be used without having to operate in a pressurized reactor.

5. The decontaminated soil can be removed from the system by centrifuge and the water content of the soil (50 percent by weight) will be sufficient in quantity to purge the system of dissolved salts. Thus, no wastewater treatment will be required on a continuous basis.

6. The maximum slurry concentration that can be agitated and pumped is 10-percent solids. This assumes that the soil has a high clay content and must be finely divided to expose more surface area to oxidation.

7. Service water and electricity will be available at each site. Steam and compressed air will be provided by equipment that is part of the process package.

3.2 Economic Evaluation

3.2.1 Capital Cost

The capital cost estimate used in this evaluation includes costs for all material, labor and engineering to design, fabricate, and construct a portable chemical degradation plant capable of processing two tons per hour of contaminated soil.

The process flow diagram (PFD) shown in Figure 3.1 was used as a basis to determine the required process equipment. The equipment was sized as indicated by the material balance shown in Table 3.1.

The total capital cost of the portable process is estimated to be 1.1 million dollars. A capital cost estimate breakdown is provided in Appendix A. Values shown are 1989 dollars and have not been escalated into future years.

Process Equipment. Equipment prices were obtained by vendor quotes, both telephone and written, for equipment shown in Figure 3.1. Recent TVA contracts and requisition prices were used for standard chemical plant equipment, i.e., pumps, tanks, agitators, screens, etc., when quotes were not available.

Structures. Cost figures from a previous TVA project (a skid-mounted, portable pilot plant containing four skids) were used to estimate the amount of material and labor required to construct portable skids for this plant.

Electrical and Instrumentation. Electrical and instrumentation estimates were prepared using the PFD as a guide and typical costs from the TVA project mentioned above.

Process Piping. General piping takeoffs were made using Figure 3.1 as a guide and also using cost figures from similar TVA projects.

Miscellaneous. Other portions of the capital cost estimate (insulation, painting, chutes, etc.) were made using established estimating principals, standards, and techniques.

Indirect Expenses. The indirect expenses expected to be encountered in a construction project of this type would include items such as:

- Construction Expenses 34 percent of Process Equipment
- Engineering Expenses 30 percent of Process Equipment
- Start-up and Testing 2 percent of Process Equipment

Contractors Fee. The usual fee or profit for a contractor can be estimated as 5 percent of direct and indirect expenses.

3.2.2 Operating Costs

The operating costs are based on an estimated 83 percent on stream factor. The process is designed for a continuous throughput of 2.4 tons per hour of contaminated soil and an average throughput of 2 tons per hour when the 83 percent on-stream factor is used.

An operating cost estimate summary is provided in Appendix A. Values shown are 1989 dollars and have not been escalated into future years.

Also included is labor and transportation cost for relocating the pilot plant. This estimate includes one move during the proposed twenty year life of the plant at a cost of $20,000.

Wages and Labor Rates. The labor rates used to determine the construction cost of the plant were obtained from the Richardson Engineering Standard Construction Cost Reporter. The national average labor rate was used for each craft to allow for construction at any U.S. location. All data includes salary, fringe benefits, overheads and where applicable, profit.

Accuracy. A contingency has not been applied to this estimate. The accuracy is expected to be within a range of 30 percent based on information shown on the PFD, Figure 3.1.

3.2.3 Cost Summary

The following table summarizes the operating costs associated with operating the portable chemical treatment plant three shifts per day, seven days per week:

	Weekly Costs	Cost/Ton Of Soil
Personnel	$10,618.46	$31.60
Office Expense	25.00	.07
Equipment	193.73	.58
Supplies	87.50	.26
Raw Materials	11,239.20	33.45
Utilities	6,089.00	18.15
Reclamation Costs	147.84	.44
	$28,409.74	$84.55

The total capital cost of the portable plant is estimated to be 1.1 million dollars (see Appendix A for details). It is also estimated, based on information provided by USATHAMA, that the total quantity of soil to be treated is 300,000 tons. At an average capacity of 2 tons per hour, the portable plant would require about 17 years to process all the contaminated soil. This time frame is less than the expected life of the plant and thus the entire capital cost can be distributed over 300,000 tons, giving a capital cost on a per ton of soil basis equal to $3.67 per ton. Adding this figure to the operating cost of $84.55 per ton (shown above) gives a total treatment cost of $88.22 per ton of soil.

IV. CHEMICAL TREATMENT TECHNOLOGY - TRANSPORTABLE PLANT DESIGN OPTIONS

The portable plant design and economic evaluation discussed in Section III was originally submitted to USATHAMA in the form of a draft report. After review of the report, a meeting was held between USATHAMA and TVA personnel to discuss possible changes to the process that could potentially lower the cost into the range of $40 to $50 per ton. The estimated chemical treatment cost of $88 per ton for the portable facility was not sufficiently lower than the targeted cost of composting (about $100 per ton) to justify the expense and risk of undertaking a research and development program.

It was subsequently decided that the study should be expanded to examine more than one type of chemical treatment process. The technology for these processes would be allowed to be drawn from current information reflecting any stage of research and development- from theoretical to patented. The study was also expanded to allow the proposed processes to be transportable, i.e., capable of being dismantled and moved to another soil decontamination site instead of being skid-mounted and portable. This allowed the soil handling rate to be increased thus lowering labor costs on a per-ton-of-soil basis.

It was also decided that two changes should be incorporated into the expanded study in order to make chemical treatment costs more comparable with the costs experienced at sites using composting and incineration technologies. First, the average explosive content of the soil was increased from 0.8 percent to 1.0 percent by weight (0.8 percent TNT plus 0.2 percent RDX). A level of 1.0 percent is an estimated average for soil from all clean-up sites. The original level of 0.8 percent was derived from experience at Cornhusker AAP. The second change was to include the costs for offices, roads, utility supply lines and other support features that would allow the chemical treatment plant to stand alone. In the portable plant study, it had been assumed that these support features would be provided by the existing ammunition plant.

Six process alternatives were selected as potential candidates to meet USATHAMA cost objectives. The six processes listed below are based on technologies that are either described in the open literature, are currently being tested, or are patented.

- Option A - Hydrolysis/Oxidation
- Option B - Shock Plasma
- Option C - Microwave/Hydrolysis/Oxidation
- Option D - Microwave/Sonic/Hydrolysis/Oxidation
- Option E - Nitric Acid/Heat
- Option F - Supercritical Fluids

For purposes of cost comparison, each process was designed to handle a maximum throughput of 9.6 tons per hour of contaminated soil. This is the largest size facility that can, on a practical basis, be dismantled and transported to another site by trucks. For purposes of cost estimation, the onstream factor was set at 83 percent, yielding an average production rate of 8 tons per hour. This is a typical onstream factor for a newly-developed process.

The battery limits of each process alternative begins with receipt of the soil from a remote site and ends with the cleaned soil being discharged to a truck ready for land reclamation. These limits were chosen to allow soil transportation and reclamation methods to be evaluated as separate alternatives. Three of these soil-handling alternatives were studied:

- Option A - Front End Loader/Truck Feed
- Option B - Onsite Slurry Pipeline/Pump
- Option C - Conveyor System Solid Feed

In each of the report sections that follow, operating costs are presented for comparison purposes. Appendix B presents details of how these costs were calculated and the assumptions used.

4.1 Soil-Handling Options

Three soil-handling options were evaluated. The three options differ only in the method by which the soil is removed from the site and transported to the chemical treatment process. The soil reclamation portion of the process is the same for all three. This generally involves hauling the soil by truck to the reclamation site, spreading the soil with a front end loader, and grass seeding.

The following sections include a brief description of each soil-handling method. All three methods are considered to be fully developed, conventional methods of moving solids. For purposes of cost estimation, all three options were considered to have a transport distance of 3,000 linear feet with relatively flat terrain between the soil site and the process. Presumably, the least costly option (Option A) would be favored at all cleanup sites although it is possible that a different distance and terrain would favor one of the other options as is discussed below.

4.1.1 Option A - Front End Loaders/Truck Solid Feed

Option A functions as follows. Soil is dug from the remediation site by front end loader and loaded to a dump truck. The truck travels by road to the chemical treatment process and unloads into a diked concrete staging area. Another front end loader moves soil from the staging area to the chemical treatment process. Two trucks are employed so that one can be loaded while the other is transporting or dumping.

This was the least costly soil-handling option at $10.61 per ton of soil (see Table 4.1 for a cost breakdown).

4.1.2 Option B - Onsite Slurry Pipeline/Pump

This option is patterned after processing methods used by the phosphate rock mining industry to transport phosphate rock over long distances. Soil is dug by front end loader and dumped into a slurry mix tank located at the digging site. Water is added to the tank to produce a slurry containing 10-percent solids. The slurry water is made up mainly of water recycled from the chemical treatment process. The soil slurry is pumped directly to the chemical treatment process via pipeline. (Note: All of the chemical treatment process options were designed to receive soil in bulk form. The process equipment would have to be rearranged differently to handle a slurry feed but the costs are not expected to be significantly changed.)

The estimated operating cost of Option B, $10.71 per ton of soil, was not significantly different from Option A (see Table 4.2 for a cost breakdown). Option B may also offer some advantages over Option A. In particular, pipeline transfer of soil would be more practical than truck transfer in locations where the terrain is rugged or muddy.

4.1.3 Option C - Conveyor System Solid Feed

This option uses a system of covered conveyor belts to move soil from the remediation site to the chemical treatment process. A front end loader is used to load the belt via hopper and vibrating feeder.

Option C was the most costly at $12.92 per ton of soil (see Table 4.3 for a cost breakdown). This option does not appear to have any advantages over the other options.

Table 4.1

SUMMARY OF OPERATING COSTS FOR
FRONT END/TRUCK SOLID FEED - OPTION A

	Weekly Cost	Cost/Ton of Soil
1. Personnel	$11,318.46	$ 8.42
2. Operating Expense	945.00	0.70
3. Equipment Expense	-	1.05
Subtotal Handling Cost	$12,263.46	$10.17
Reclamation Costs		.44
TOTAL SOIL HANDLING COSTS		$10.61

Table 4.2

SUMMARY OF OPERATING COSTS FOR
ONSITE SLURRY PIPELINE/PUMP - OPTION B

	Weekly Cost	Cost/Ton of Soil
1. Personnel	$ 9,530.77	$ 7.09
2. Operating Expense	630.00	0.47
3. Equipment Expense		1.56
4. Relocation Expense		1.15
Subtotal Handling Cost	$10,160.77	$10.27
Reclamation Costs		.44
TOTAL SOIL HANDLING COSTS		$10.71

Table 4.3

SUMMARY OF OPERATING COSTS FOR
CONVEYOR SYSTEM SOLID FEED - OPTION C

	Weekly Cost	Cost/Ton of Soil
1. Personnel	$ 9,530.77	$ 7.09
2. Operating Expense	630.00	0.47
3. Equipment Expense		2.88
4. Relocation Expense		2.05
Subtotal Handling Cost	$10,160.77	$12.48
Reclamation Costs		.44
TOTAL SOIL HANDLING COSTS		$12.92

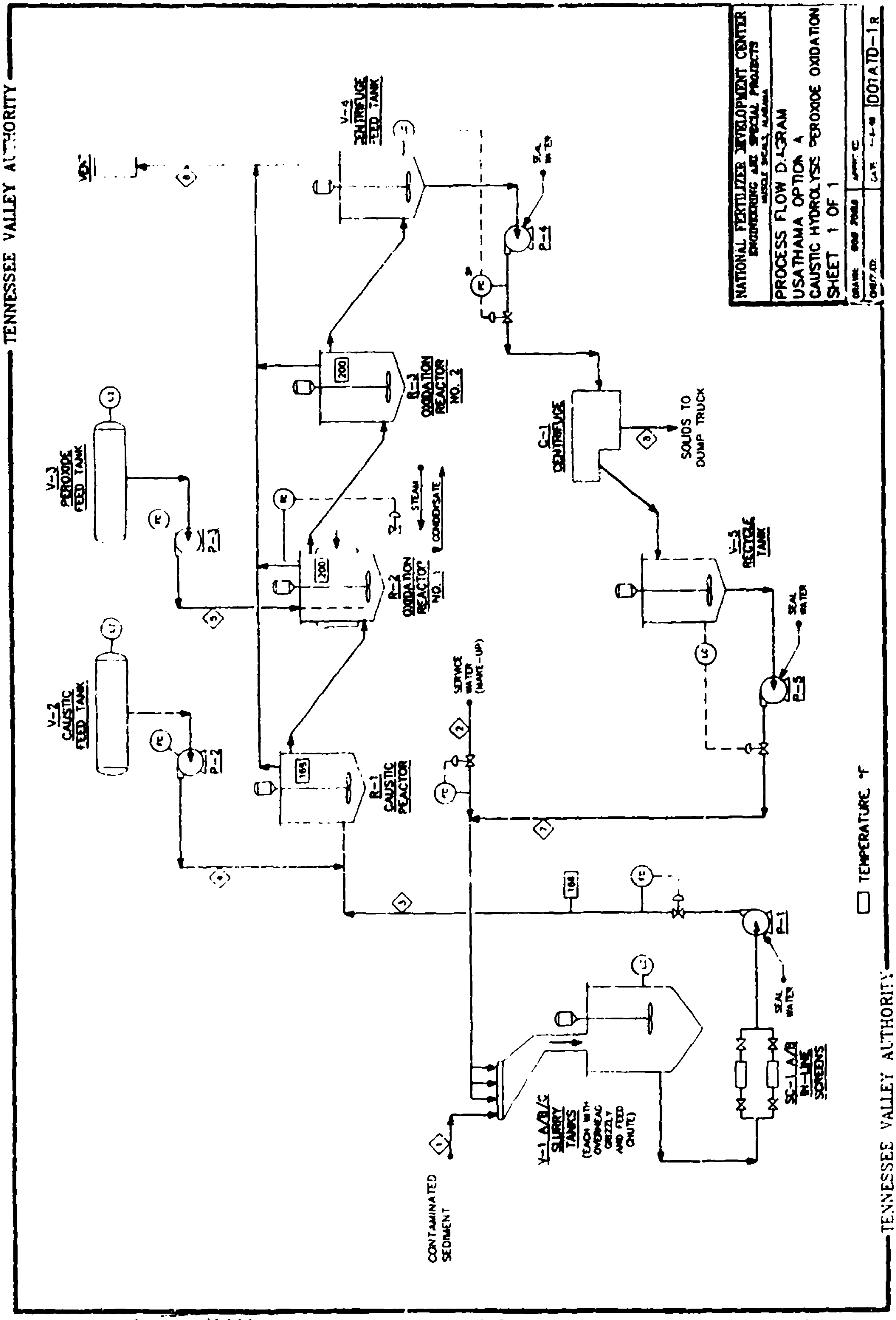
4.2 Chemical Treatment Process Options

Out of the six process options examined, only three could be carried all the way through the process design stage to a cost estimate. These were Options A, C, and F. The remaining options (B, D, and E) were judged unsuitable during the investigation stage for differing reasons as described in the following sections.

4.2.1 Option A - Hydrolysis/Oxidation

This is essentially the same process as the portable process proposed in Section III except that the soil feed rate was increased from 2.4 tons per hour to 9.6 tons per hour. This also had the effect of changing the process from one that was portable (fully assembled on flatbed truck trailers) to one that was transportable (could be disassembled and transported by truck). A process flow diagram for Option A is shown in Figure 4.1. A material balance is given in Table 4.4.

Process Description. Explosive-contaminated lagoon soil is delivered to one of three identical slurrying tanks (V-1 A, B, C). The soil delivery method may be any one of three alternative methods discussed in Section 4.1. Each slurrying tank is equipped with an overhead grizzly screen to remove stones and other oversize material. Recycle water from the process is applied to the grizzly screen using spray nozzles to break up chunks and slurry the soil. Makeup water is added to produce a slurry containing about 10-percent solids. The purpose of having three slurry tanks is to provide sufficient holding time (about one hour each) to analyze the explosives content of each batch. This will ensure that the proper chemical addition rate is used later in the process, and it will aid in achieving decontamination at minimum cost.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ENGINEERING AND SPECIAL PROJECTS
PROCESS FLOW DIAGRAM
USATHAMA OPTION A
CAUSTIC HYDROLYSIS PEROXIDE OXIDATION
SHEET 1 OF 1
D01ATD-1R
V-2 CAUSTIC FEED TANK
V-3 PEROXIDE FEED TANK
V-4 CENTRIFUGE FEED TANK
R-1 CAUSTIC REACTOR
R-2 OXIDATION REACTOR NO. 1
R-3 OXIDATION REACTOR NO. 2
STEAM
CONDENSATE
C-1 CENTRIFUGE
SOLIDS TO DUMP TRUCK
V-5 RECYCLE TANK
SEAL WATER
SERVICE WATER (MAKE-UP)
V-1 A/B/C SLURRY TANKS (EACH WITH OVERHEAD GRIZZLY AND FEED CHUTE)
SC-1 A/B IN-LINE SCREENS
CONTAMINATED SEDIMENT
TEMPERATURE °F
P-1
P-2
P-3
P-4
P-5
165
200
200
164
TENNESSEE VALLEY AUTHORITY

Figure 4.1

Table 4.4

USATHAMA PROCESS OPTION A - CAUSTIC HYDROLYSIS/PEROXIDE OXIDATION
MATERIAL BALANCE

Stream No.	1	2	3	4	5	6	7	8
Description	Soil Feed	Makeup Water	Slurry Feed	Caustic Feed	Peroxide Feed	Vent Gases	Recycle Water	Recovered Soil
Component	Flow Rate, Pounds Per Hour							
H_2O	4788	8732	129285	123	223	794	115605	14174
Solids	14174	-	14920	-	-	-	746	14174
TNT	153	-	153	-	-	-	-	-
RDX	38	-	38	-	-	-	-	-
NaOH	-	-	-	123	-	-	-	-
Na_2CO_3	-	-	261	-	-	-	261	32
$NaNO_3$	-	-	2133	-	-	-	2133	262
H_2O_2	-	-	-	-	523	-	-	-
CO_2	-	-	-	-	-	221	-	-
TOTAL	19153	8732	146790	246	746	1015	118745	28642

The soil slurry is first pumped to the caustic reactor (R-1). Here the explosives are hydrolyzed (i.e., nitrate groups are removed from the TNT molecular structure) by addition of 50-percent caustic to begin the decomposition. The caustic reactor is equipped with agitation to maintain slurry conditions and has a residence time of 30 minutes. The caustic reactor overflows to the first of two agitated oxidation reactors (R-2 and R-3) arranged in series. Each reactor provides 30 minutes residence time. Hydrogen peroxide (H_2O_2) was selected as the oxidant because it is inexpensive compared to other chemical oxidizers and because, after reacting, only water remains as residue. All of the hydrogen peroxide is added in the first reactor. Steam is applied to the jacket of the first reactor to raise the reaction temperature to 200°F to enhance the reaction rate. During oxidation, the carbon in the explosive materials is converted to carbon dioxide and the hydrogen is converted to water. Some carbon dioxide remains in solution as sodium carbonate and the remainder escapes through the reactor vent system. Nitrogen from the explosive remains in solution as sodium nitrate.

After passing through the sacond oxidation reactor, the soil is now decontaminated and ready to be removed from the system. The decontaminated soil slurry is pumped to a continuous centrifuge which removes the soil as a cake containing 50-percent solids. The moisture in the cake is considered to be sufficient in quantity to purge the system of dissolved salts, thus preventing a buildup of sodium in the water circulation loop. The filtrate from the centrifuge is recycled to the slurry tank (V-1 A, B, or C) to complete the circulation loop.

<u>Process Assumptions</u>. Because this process is theoretical in nature, certain assumptions had to be made in order to assemble a complete design. These assumptions are listed below.

1. The average explosives content of the soil to be treated is one percent which includes 0.8 percent TNT and 0.2 percent RDX. These numbers were provided by USATHAMA personnel and were based on samplings of soil experienced to date. This is a key assumption because the quantity of chemical reactants (and their costs) will increase or decrease proportionately with the explosives content of the soil.

2. The addition rate of caustic to the hydrolysis reactor will be 20 percent in excess of the stoichiometric requirement and the reactor will require a 30-minute residence time. The excess caustic reacts with carbon dioxide in the oxidation reactors to form sodium carbonate.

3. The addition rate of hydrogen peroxide will be equal to the stoichiometric requirement and the reactor will require a 60-minute residence time. This is perhaps the weakest assumption because, generally, an excess over stoichiometric is required to drive a reaction to completion. Also, organic matter in the soil is expected to compete with the explosives for oxidant. However, naturally-occurring dissolved oxygen in the slurry is expected to contribute to a portion of the oxidation and thus make up any deficiency in peroxide.

4. An elevated temperature will be required to make the oxidation reaction proceed. A temperature of 200°F was selected as a practical temperature that could be used without having to operate in a pressurized reactor.

5. The decontaminated soil can be removed from the system by centrifuge and the water content of the soil (50 percent by weight) will be sufficient in quantity to purge the system of dissolved salts. Thus, no wastewater treatment will be required on a continuous basis.

6. The maximum slurry concentration that can be agitated and pumped is 10-percent solids. This assumes that the soil has a high clay content and must be finely divided to expose more surface area to oxidation.

Discussion. The estimated operating cost for Option A is $98.30 per ton of soil not including handling costs (see table 4.5 for a cost breakdown). Option A had the lowest operating cost of the options studied. This option was also the lowest in capital cost, $2,806,000 (see Table 4.6 for a cost breakdown).

A cost comparison between Option A and the similar smaller portable facility presented in Section III showed that the increase in production rate did not lower the total operating cost on a per-ton basis. Personnel expense was reduced as expected from more than $30 per ton in the smaller plant to less than $8 per ton. This reflected a fourfold increase in production rate without having to increase operating personnel. However, the capital expenses on a per-ton basis increased for Option A from $3.67 per ton to $9.66 per ton because a fixed amount of soil (300,000 tons) is being processed using a more expensive facility. It should be noted that this amount of soil can be completely processed at 8 tons per hour in a period of about five years which is much less time than the estimated 15- to 20-year plant life. If it is discovered that the amount of soil to be processed exceeds 300,000 tons, then the capital charge per ton of soil will be reduced proportionately.

Option A also incurred large moving expenses ($15.36 per ton) for dismantling and reconstructing the facility. These expenses were minimal for the fully-assembled portable facility. Two relocations (three operating sites) were figured into the costs. If it is determined in the future that there are numerous cleanup sites, then the portable facility would have a distinct advantage over a transportable facility.

Table 4.5

OPERATING COSTS FOR THE EIGHT-TON-PER-HOUR HYDROLYSIS/OXIDATION PROCESS - OPTION A

	Weekly Cost	Cost/Ton of Soil
1. Personnel	$10,553.85	$ 7.85
2. Office Expense	25.00	0.02
3. Pilot-Plant Supplies	87.50	0.07
4. Raw Materials	65,213.40	48.52
5. Pilot-Plant Utilities	21,603.12	16.07
Subtotal - Operating Costs	$97,482.87	$72.53
6. Plant Expense (Capital)		9.35
7. Relocation Expense (Capital)		11.76
8. Facilities Expense (Capital)		4.65
TOTAL COST	$97,482.87	$98.30

Table 4.6

CAPITAL COST ESTIMATE FOR THE EIGHT-TON-PER-HOUR HYDROLYSIS/OXIDATION PROCESS - OPTION A

	Material	Labor Hours	Labor Costs	Total Costs
Process Equipment	$ 648,050	10,575	$252,740	$ 900,790
Concrete	45,439	2,251	44,110	89,549
Piping	166,768	6,676	159,564	326,332
Steel	49,470	2,085	48,157	97,627
Instrumentation	49,679	2,088	48,867	98,546
Insulation	22,225	1,010	23,434	45,659
Electrical	135,723	5,295	123,892	259,615
Painting	6,463	582	10,941	17,403
Subtotal	$1,123,816	30,561	$711,704	$1,835,520

Subtotal Direct Costs	$1,835,520
Engineering and Supervision	226,818
Construction Expense	220,337
Startup and Test	36,710
Contractor's Fee	139,163
Contingency	347,908
Fixed Capital Investment	$2,806,455

The total operating cost for Option A including the least costly soil-handling option (Option A, $10.61 per ton) is about $109 per ton of soil. This is about $21 higher than the estimate for the smaller, portable process. About $20 of this difference comes from a change in the basis for the economic evaluation. The basis change in the explosive content of the soil (from 0.8 percent to 1.0 percent) increased the chemical costs and the addition of stand alone support facilities (roads, utility lines, etc.) also increased costs. The remaining $1 increase is attributable to the increase in the facility size as discussed above.

It should be noted that even though Option A is the least expensive of the options studied, there is a high risk in it of being successfully developed and demonstrated. Option A is theoretical and is thus relatively untested. A number of possibilities exist that could increase the operating cost in the fully-developed process. For example, the process may require more than the stoichiometric amount of peroxide. It is also possible that other types of oxidant chemicals will be required that are more powerful (and more expensive) than hydrogen peroxide. Many other possibilities exist. On the plus side, however, the research phase of the project may find processing methods that will help lower the cost (e.g., catalysts that will allow more oxygen from the air to be used in place of chemical oxidants).

The Option A process design reflects an effort to make the process as simple and inexpensive as possible, given the very wide design latitude that is possible for a theoretical process. All of the vessels are made of fiberglass except for the steam-jacketed oxidation reactor, R-2. The process does not require any pressurized equipment or specialty materials of construction. All of the pumps are standard off-the-shelf items. The feed chemicals (caustic and hydrogen peroxide) are among the least expensive of their respective types. The point of this discussion is to state that it would be difficult to envision a chemical process with a significantly lower operating cost than Option A. If an objective operating cost of $40-50 per ton is to be closely approached, it will require unusual circumstances (e.g., being able to obtain a free oxidizer chemical as a waste material from the Army). On this basis, it is concluded that any form of chemical treatment--where the contaminated soil is removed from the site, treated in chemical process equipment, and then reclaimed--has a low probability of meeting the cost objective.

4.2.2 Option B - Shock Plasma

Shock plasma is a process in which organic waste is destroyed by heating it with an electric arc to an extremely high temperature (20,000°C - 50,000°C). Plasma technology has been available for many years and has been mainly used in the metallurgical industry. The Neutrail Company in Massachusetts has adapted plasma technology as a method of destroying sewage sludge. In this process, sewage sludge is fed into the top of a refractory-lined reactor vessel. As the sludge freefalls by gravity, it enters a reactor zone where a strong electric arc heats the sludge to plasma temperature. The organic material in the sludge is broken down into highly reactive atomic species. As this reactive sludge leaves the plasma zone, it is mixed with air. Oxygen in the air reacts rapidly with the carbon and hydrogen from the organic matter to form harmless carbon dioxide and water vapor.

The Neutrail Company was contacted by TVA to obtain information that would enable a process design and cost estimate to be made for plasma treatment of contaminated soil. Since this process is currently being developed by Neutrail, it was not possible to obtain sufficiently detailed information to make a cost estimate. However, Neutrail personnel stated that processing costs for sewage sludge range from about $140 to $160 per ton. These costs are expected to be higher for contaminated soil because (1) the relatively low organic content of contaminated soil would produce much less heat during oxidation than sludge, increasing electricity requirements for the plasma arc, and (2) the high ash content of soil would require much larger ash-handling equipment.

If this process is considered as a potential soil decontamination method, then one safety concern should be addressed. Presumably, in order to minimize energy requirements, soil would have to be fed to this process as received without slurrying in water. Although heating to plasma conditions occurs very rapidly, it is possible that explosive-rich soil could detonate high order during transition to plasma temperature.

4.2.3 Option C - Microwave/Hydrolysis/Oxidation

Process Description. A process flow diagram for Option C is shown in Figure 4.2. A material balance is given in Table 4.7. Option C is a simple modification of Option A adapted to use microwave energy in place of half of the hydrogen peroxide. The microwave oxidation takes place (in theory) when microwave energy breaks an organic bond and oxygen from the air reacts at the bond breakpoint. The air is supplied to oxidation reactor no. 1 (R-2) by an external air compressor. The microwave power requirement is estimated to be 1,800 kilowatts (kW). This is supplied by 36 50-kW, water-cooled microwave generators with metal ductwork to channel the microwaves.

Process Assumptions. Two assumptions were made in addition to those described for Option A.

1. The combination of microwave energy and air feed can be substituted for half of the hydrogen peroxide oxidant. This assumption is untested.

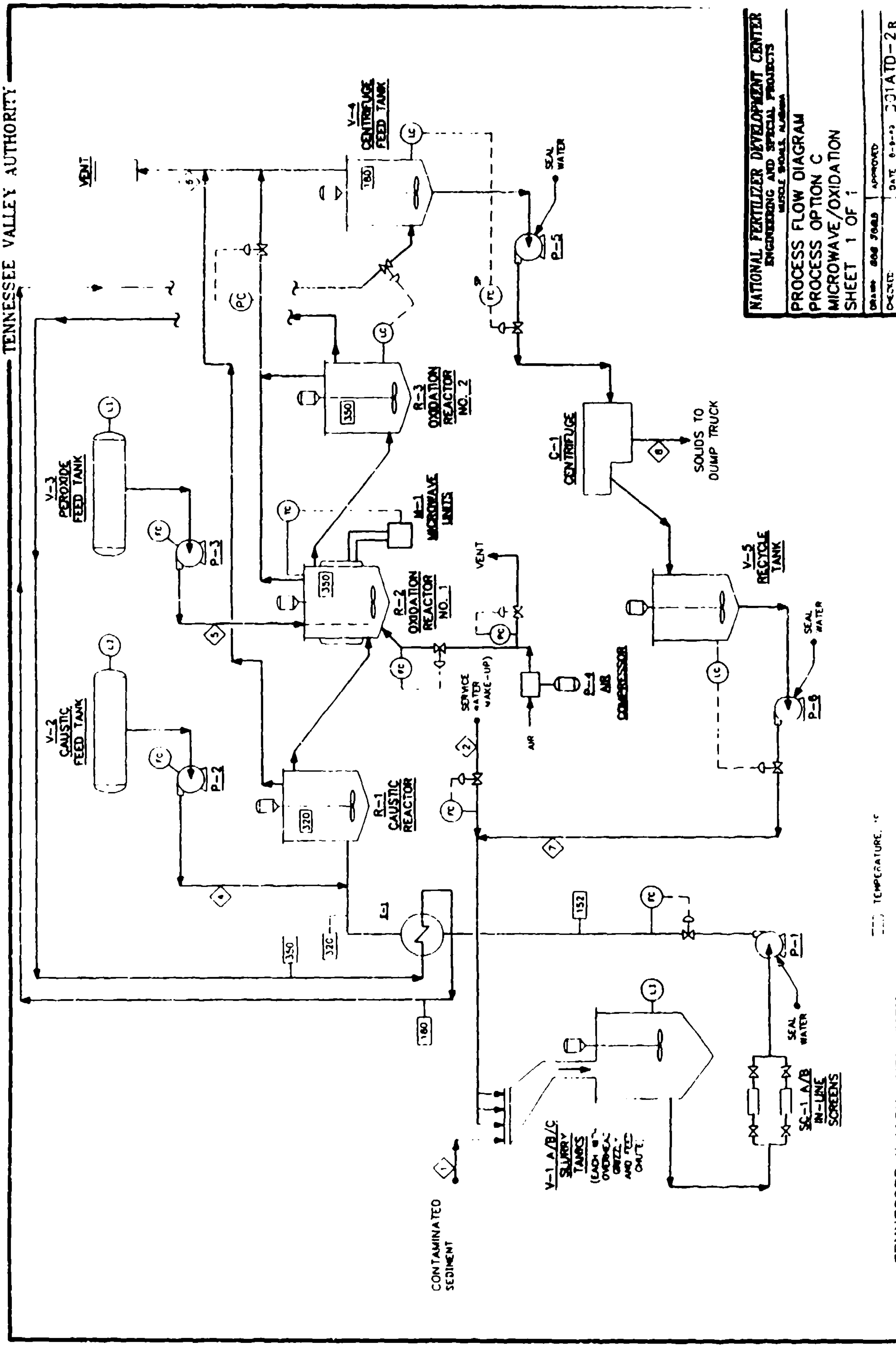

TENNESSEE VALLEY AUTHORITY
NATIONAL FERTILIZER DEVELOPMENT CENTER
ENGINEERING AND SPECIAL PROJECTS
PROCESS FLOW DIAGRAM
PROCESS OPTION C
MICROWAVE/OXIDATION
SHEET 1 OF 1
VENT
V-4 CENTRIFUGE FEED TANK
V-3 PEROXIDE FEED TANK
V-2 CAUSTIC FEED TANK
R-3 OXIDATION REACTOR NO. 2
M-1 MICROWAVE UNITS
R-2 OXIDATION REACTOR NO. 1
R-1 CAUSTIC REACTOR
C-1 CENTRIFUGE
SOLIDS TO DUMP TRUCK
V-5 RECYCLE TANK
P-1
P-2
P-3
P-5
P-6
P-4 AIR COMPRESSOR
SEAL WATER
SERVICE WATER (MAKE-UP)
AIR
E-1
V-1 A/B/C SLURRY TANKS
SC-1 A/B IN-LINE SCREENS
CONTAMINATED SEDIMENT
TEMPERATURE, °C

Figure 4.2

Table 4.7

USATHAMA PROCESS OPTION C - MICROWAVE/OXIDATION
MATERIAL BALANCE

Stream No.	1	2	3	4	5	6	7	8	9
Description	Soil Feed	Makeup Water	Slurry Feed	Caustic Feed	Peroxide Feed	Vent Gases	Recycle Water	Recovered Soil	Oxidizing Air
Component	Flow Rate, Pounds Per Hour								
H_2O	4788	10436	129285	123	112	2248	113901	14174	-
Solids	14174	-	14909	-	-	-	735	14174	-
TNT	153	-	153	-	-	-	-	-	-
RDX	38	-	38	-	-	-	-	-	-
NaOH	-	-	-	123	-	-	-	-	-
Na_2CO_3	-	-	257	-	-	-	257	32	-
$NaNO_3$	-	-	2102	-	-	-	2102	262	-
H_2O_2	-	-	-	-	261	-	-	-	-
CO_2	-	-	-	-	-	221	-	-	-
O_2	-	-	-	-	-	246	-	-	369
N_2	-	-	-	-	-	1199	-	-	1199
Ar	-	-	-	-	-	24	-	-	24
TOTAL	19153	10436	146744	246	373	3938	116995	28642	1592

2. The reaction temperature for microwave oxidation to proceed must be at least 350°F. This assumption is based on informal tests conducted at TVA on behalf of projects not related to USATHAMA work.

Discussion. Option C was originally proposed as a means of reducing the high cost of chemical feeds in Option A. In this respect, it was successful at reducing raw material costs from about $48 per ton for Option A to about $35 per ton (chemical costs plus electric power costs to operate the microwave generators). However, the purchase costs of the microwave generators, their bulky size and weight, and the cost of electrical transmission equipment dramatically increased capital charges (plant expense) and relocation expense. These two expense categories totalled about $98 per ton of soil for Option C as compared to $25 for Option A. The net effect increased the overall operating cost per ton of soil from $98.30 in the case of Option A to $146.22 for Option C (see Table 4.8 for a cost breakdown of Option C). Capital costs for Option C were $13,511,000 (see Table 4.9 for a cost breakdown).

4.2.4 Option D - Microwave/Sonic/Hydrolysis/Oxidation

This option was proposed as a further modification to Option C by the addition of sonic-wave-generating equipment. It has been theorized that high-frequency sonic waves could enhance microwave oxidation and thus further reduce hydrogen peroxide requirements. However, investigation revealed that sonic oxidation is not technically feasible for two reasons: (1) sonic-wave-generating equipment is not available in the size and power range that would be required for this process and (2) no evidence could be found that sonic waves are capable of supplying energy at the molecular level to break compound bonds. Therefore, no cost estimate was made for Option D.

Table 4.8

OPERATING COSTS FOR THE EIGHT-TON-PER-HOUR MICROWAVE/OXIDATION PROCESS - OPTION C

	Weekly Cost	Cost/Ton of Soil
1. Personnel	$13,526.15	$10.06
2. Office Expense	25.00	0.02
3. Pilot-Plant Supplies	87.50	0.07
4. Raw Materials	35,448.00	26.38
5. Pilot-Plant Utilities	12,782.40	9.51
Subtotal - Operating Costs	$61,869.05	$46.03
6. Plant Expense (Capital)		45.04
7. Relocation Expense (Capital)		50.63
8. Facilities Expense (Capital)		4.53
TOTAL COST	$61,869.05	$146.22

Table 4.9

CAPITAL COST ESTIMATE FOR THE EIGHT-TON-PER-HOUR
MICROWAVE OXIDATION PROCESS - OPTION C

	Material	Labor Hours	Labor Costs	Total Costs
Process Equipment	$ 3,375,400	47,077	$ 843,850	$4,219,250
Concrete	200,482	10,345	202,762	403,244
Piping	512,499	19,240	459,824	972,323
Steel	115,558	5,087	117,512	233,070
Instrumentation	367.638	18,090	423,294	790,932
Insulation	154,697	6,369	147,763	302,460
Electrical	947,541	36,884	863,090	1,790,631
Painting	20,682	585	11,006	31,687
Subtotal	$ 5,674,496	143,677	$3,069,101	$8,743,597

Subtotal Direct Costs	$ 8,743,597
Engineering and Supervision	1,181,390
Construction Expense	1,147,636
Startup and Test	113,490
Contractor's Fee	664,357
Contingency	1,660,893
Fixed Capital Investment	$13,511,364

4.2.5 Option E - Nitric Acid/Heat

The technology for this option is based on ongoing work at TVA to find a simple, inexpensive method of destroying pesticides in contaminated farm equipment rinse solutions. It was believed that a similar technology could be applied to contaminated soils.

The basic process concept uses nitric acid, heat, and bubbling air to oxidize the organic explosive compounds. The nitric acid not only enhances oxidation by the air but is capable of donating oxygen directly as an oxidizer. The high cost of using large quantities of nitric acid is offset by converting the high-nitrate, soil-free filtrate from the process into a marketable fertilizer--urea ammonium (UAN) solution.

After making a preliminary process design and material balance, Option E was dropped from further consideration for several reasons. First, the fact that the soil must be heavily diluted to be pumpable means that huge quantities of nitric acid would be required. This in turn would force the Army to have to market several hundred tons per day of UAN solution. Also, the preliminary raw material costs were very high on a per-ton-of-soil basis despite the offsetting value of the UAN solution.

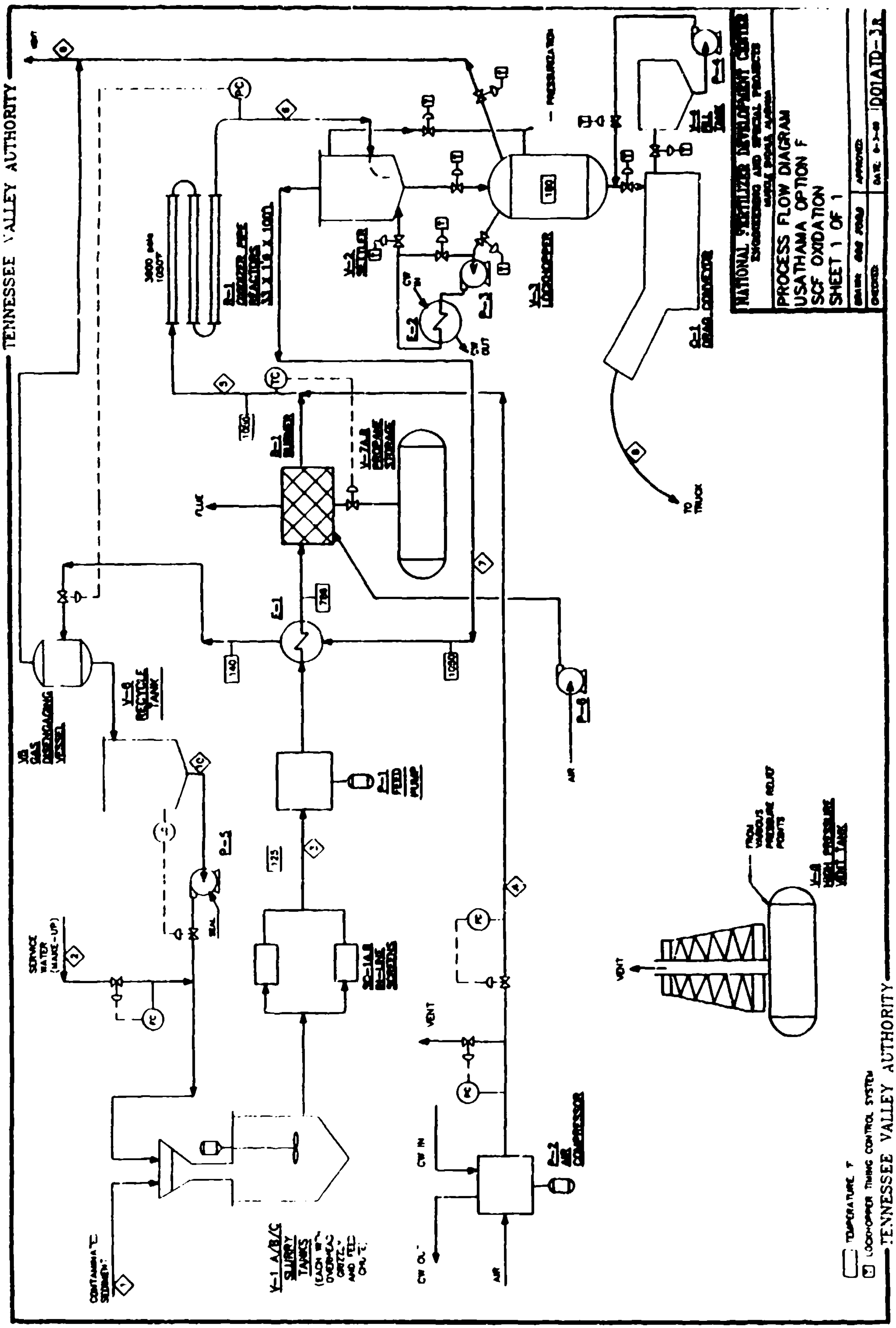
4.2.6 Option F - Supercritical Fluids Oxidation

Supercritical fluids (SCF) oxidation is a patented process (patent no. 4,543,190, September 1985) invented by Michael Modell of Modar, Inc, in Massachusetts. The process as described in the patent uses conditions of high pressure (>3,200 psia) and temperature (>752°F) in combination with injected air or oxygen to completely oxidize an organic waste. The patent process is generally applied to treat sewage sludges, liquid organic wastes, and other high heat content wastes. Although the patent does not specifically mention contaminated soils as a treatable waste, the process should work equally well to destroy all organic forms including explosives. With soils, however, process heat must be supplied from an external source since the waste soil has little heating value. Special provision must also be made to remove a relatively large quantity of inorganic soil solids from the pressurized system.

A proposed process for treatment of explosive-contaminated soils by SCF oxidation is shown in Figure 4.3. A material balance is given in Table 4.10.

<u>Process Description</u>. Explosive-contaminated lagoon soil is delivered to one of three identical slurrying tanks (V-1 A, B, C). The soil delivery method may be any one of three alternative methods discussed in Section 4.1. The soil slurry concentration is set at about 10-percent solids using recycle water from the process plus added makeup water. Essentially, the soil slurrying portion of the process functions the same as in Option A.

Fresh soil slurry is pumped up to the process operating pressure (3,600 psia) using a positive displacement pump (P-1). This high-pressure slurry first passes through heat exchanger E-1 where the slurry is preheated by recovering heat from process recycle water on its way back to the front end of the process. The feed slurry then passes through a propane burner/heat exchanger (B-1) to raise the slurry to the recommended reaction temperature of 1,050°F. The hot slurry is then mixed with compressed air and delivered to the first of 33 sequential pipe reactors where oxidation of the explosives takes place. At the supercritical conditions of 3,600 psia and 1,050°F, the air is completely soluble in the water slurry as a single phase. Thus, the reaction takes place quickly in less than five minutes. The oxidation pipe reactors (R-1) are a system of 33 one-foot-diameter, 100-foot-long stainless steel pipes.



TENNESSEE VALLEY AUTHORITY
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PROCESS FLOW DIAGRAM
USATHAMA OPTION F
SCF OXIDATION
SHEET 1 OF 1
TENNESSEE VALLEY AUTHORITY

Figure 4.3

Table 4.10

USATHAMA PROCESS OPTION F - SCF OXIDATION
MATERIAL BALANCE

Stream No.	1	2	3	4	5	6	7	8	9	10
Description	Soil Feed	Makeup Water	Slurry Feed	Air	Reactor Feed	Reactor Effluent	Settler Effluent	Recovered Soil	Vent Gases	Recycle Water
Component	Flow Rate, Pounds Per Hour									
H_2O	4788	9443	127566	-	127566	127578	113404	14174	229	113175
Solids	14174	-	14174	-	14174	14174	-	14174	-	-
TNT	153	-	153	-	153	-	-	-	-	-
RDX	38	-	38	-	38	-	-	-	-	-
N_2	-	-	-	1185	1185	1185	1066	-	1185	-
O_2	-	-	-	364	364	121	109	-	121	-
Ar	-	-	-	24	24	24	22	-	24	-
HNO_3	-	-	-	-	-	192	-	192	-	-
CO_2	-	-	-	-	-	230	207	-	230	-
TOTAL	19153	9443	141931	1573	143504	143504	114808	28540	1789	113175

The number of reactors, their diameter, and their length is an arbitrary arrangement of pipes to achieve a five-minute residence time while maintaining sufficient velocity to maintain slurry conditions without settling. Other arrangements are possible. The SCF patent requires that these reactors be constructed of materials such as Hastelloy C or equivalent to resist corrosion from chlorides. However, most soils are low in chlorides and thus less expensive stainless steel (type 316) was chosen for the reactors and downstream equipment.

The decontaminated slurry leaves the reactor system and enters a settler/lockhopper system. This system separates the soil from the recycle water, cools the soil, and removes it from the pressurized portion of the process. The first vessel in this system, the settler (V-2), simply reduces the flow velocity of the slurry allowing the solids to separate by gravity. The low viscosity experienced in supercritical water enables settling to occur quickly. The lockhopper (V-3) and associated equipment functions to cool and remove the soil using a timed cycle of valve openings and closings. During most of the cycle, the lockhopper operates at full system pressure (3,600 psia) as it fills with soil that falls by gravity from the settler. A cooling circulation loop pulls water from the top of the lockhopper, pumps it through a cooling exchanger (E-2), and feeds it to the bottom of the settler. This flow serves to cool the soil and helps to sweep the soil through the line and valve between the settler and lockhopper. When the lockhopper is filled with solids, the timer closes the valve between the settler and lockhopper and isolates the cooling loop. Next, the lockhopper is depressurized to a vent to remove dissolved gases. After depressurization, the valve below the lockhopper opens and the contents (soil and water) are emptied to a drag conveyor (C-1). Soil settles in the drag conveyor and is removed by moving flights to a dump truck underneath. After the soil is removed, water remaining behind is channeled to a fill tank (V-4) and is then pumped to the lockhopper to refill it (with the bottom valve closed). The lockhopper is then pressurized using a small diameter pipeline between the settler and lockhopper. Next, the valve above the lockhopper is opened and the cooling loop flow is re-established to complete the cycle.

The soil-free water that leaves the top of the settler is now ready to be returned to the front end of the process for re-slurrying. The water first passes through exchanger E-1 where it is cooled to about 140°F. Next, a pressure control valve (that maintains system backpressure) releases the flow of water to atmospheric pressure in a gas disengaging vessel (V-5). Dissolved gases flash out and are routed to vent. The gases include nitrogen from the reactor air feed, a small amount of unreacted oxygen, and carbon dioxide from the oxidation of the explosives. According to the patent, trace amounts of nitrogen oxides may also be formed. The nitrogen from the explosives, however, remains in solution in nitrate form and is purged out of the system with the soil.

Water from the gas disengaging vessel is pumped back to the slurry tanks to complete the recycle loop. The list of process equipment also includes a high pressure vent tank (V-8) to capture hot soil and water and to vent flashing steam in the event that pressure safety valves in the process are activated.

<u>Process Assumptions</u>. Since this process is patented and well defined, no process assumptions were required. However, because the patent process has been applied only in small-scale equipment and because it has not been applied to soils, there are many questions regarding the fabrication of equipment pieces and their function. These questions are discussed below.

<u>Discussion</u>. The total operating cost of Option F, $234.96 per ton of soil, was the highest of the options studied (see Table 4.11 for a

Table 4.11

OPERATING COSTS FOR THE EIGHT-TON-PER-HOUR
SCF/OXIDATION PROCESS - OPTION F

	Weekly Cost	Cost/Ton of Soil
1. Personnel	$15,863.08	$11.80
2. Office Expense	25.00	0.02
3. Pilot-Plant Supplies	122.50	0.09
4. Raw Materials	0.00	0.00
5. Pilot-Plant Utilities	61,126.80	45.48
Subtotal - Operating Costs	$77,137.38	$57.39
6. Plant Expense (Capital)		77.33
7. Relocation Expense (Capital)		95.71
8. Facilities Expense (Capital)		4.53
TOTAL COST	$77,137.38	$234.96

cost breakdown). This cost was due mainly to a high capital cost ($23,198,196) and a very high relocation expense ($96.01 per ton of soil). (See Table 4.12 for a capital cost breakdown.) Because this process requires structural steel for the heavy high-pressure equipment, it cannot truly be considered as a transportable process. Nevertheless, a relocation expense was estimated for comparison with other options.

Even though Option F was the most costly, it has one major advantage over other options. This advantage is the certainty that it will effectively destroy all of the explosive contamination in the soil. The other options (A and C) will require considerable research and development work.

The application of SCF oxidation to soils leaves many questions regarding the fabrication of equipment and the proper functioning of equipment. These concerns are enumerated below.

1. It may be very difficult to find a suitable feed pump (P-1) that is capable of pumping soil slurries at the desired pressure 3,600 psia. The main problem lies with the pump check valves which must form a tight seal to achieve high pressure. Soil will contain pebbles, sticks, roots, and other odd-shaped materials that could easily jam in a check valve and prevent proper seating.

2. The SCF patent only briefly suggests types of solids separation equipment without going into details of operation. As described earlier, the settler/lockhopper system will be complex. Thus, there are questions concerning the smooth flow of soil through the system. These questions mainly involve the possibility of pluggage at the bottom of the settler or lockhopper and the possibility that the large ball valves above and below the lockhopper will become jammed by trash material or stones.

Table 4.12

CAPITAL COST ESTIMATE FOR THE EIGHT-TON-PER-HOUR SCF OXIDATION PROCESS - OPTION F

	Material	Labor Hours	Labor Costs	Total Costs
Process Equipment	$ 7,159,600	99,855	$1,431,920	$ 8,591,520
Concrete	294,531	14,654	287,214	581,744
Piping	1,302,356	51,302	1,226,113	2,528,469
Steel	317,248	14,143	326,714	643,961
Instrumentation	261,421	12,023	281,345	542,766
Insulation	133,877	5,327	123,593	257,470
Electrical	403,714	18,772	439,274	842,988
Painting	30,691	2,587	48,637	79,327
Subtotal	$ 9,903,436	218,664	$4,164,809	$14,068,245

Subtotal Direct Costs	$14,068,245
Engineering and Supervision	2,505,860
Construction Expense	2,434,264
Startup and Test	198,069
Contractor's Fee	1,140,502
Contingency	2,851,255
Fixed Capital Investment	$23,198,196

3. The service life of the pressure control valve between E-1 and V-5 may be very short causing frequent plant stoppages. The 3,600-pound pressure drop across this valve is expected to produce a high erosion rate to the valve seat and plug even if specialty coatings are employed. The erosion source will be very fine-sized particulate matter remaining in the settler effluent.

4. Considering the large size of the facility and the severe pressure and temperature operating conditions, some of the process equipment may be very difficult to fabricate and install. For example, to meet safety codes, the settler will require stainless steel walls at least 16-inches thick.

V. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study showed that it is highly unlikely that any form of chemical treatment processing would be capable of decontaminating explosive-contaminated soil at a cost significantly less than the $100 per ton of soil cost targeted for composting technology (for example, $40-$50 per ton of soil). Although it is not possible to evaluate all of the processes that are potentially workable, this conclusion can still be stated with a high degree of confidence. For each theoretical process that was studied, simplifying assumptions were used so as to show the economic potential of the process and each cost category (labor, raw materials, etc.) was examined to determine if costs could be lowered.

The least costly process studied was hydrolysis/oxidation which was evaluated as both a small, skid-mounted portable process and as a larger transportable process (Option A). The feed chemicals (caustic and hydrogen peroxide) are among the least expensive of their respective types. Furthermore, chemical quantities were minimized by assuming stoichiometric addition in the case of peroxide and slightly above stoichiometric for caustic. Thus the chemical types and quantities that were chosen formulate the least expensive combination possible for direct chemical action to oxidize the explosive contaminants.

Other options examined the possibility of reducing chemical usage by substituting heat and air for direct chemical action. Option C theorized the use of microwave energy plus injected air to oxidize up to half of the explosive contaminants. Option F theorized the use of extreme pressure and temperature (supercritical conditions) with injected air to eliminate all of the chemical requirements. However, the savings that were achieved by eliminating chemical costs were more than offset by the expense of electricity, fuel, equipment (capital), and the cost of disassembling and moving the additional equipment from site to site.

Since chemical costs (or their equivalent) could not be lowered, labor costs were examined. By scaling up the skid-mounted portable process by a factor of four such that it was now a transportable process (Option A), the labor costs were cut significantly from about $32 per ton of soil to about $8 per ton of soil. However, these savings were offset by the increase in capital expenses ($10 per ton) plus moving expenses ($15 per ton) for dismantling and reconstructing the transportable process. Thus, the transition from a portable process to a transportable process erased the economy of scale.

The remaining cost categories (utilities, office supplies, etc.) were relatively small and for the most part were unchangeable.

5.2 Recommendations

No further study of chemical treatment is recommended unless the cost of composting technology escalates well beyond the targeted cost of $100 per ton of soil when it is fully developed by USATHAMA.

APPENDIX A

COST ESTIMATION DETAILS FOR THE PORTABLE PROCESS DESIGNS

INFORMATION SHEET
****

Estimate No. 3755 — Work Order No. DO1ATD

Project: USATHAMA - PROCESS FOR CHEMICAL TREATMENT OF EXPLOSIVE CONTAMINATED SOIL (W/ PACK. BOILER & AIR COMP.)

Prepared by: L BISHOP
Cost by: L BISHOP
Date Prepared: 1/4/89

Type: ORDER OF MAGNITUDE

Project Description:
====================
This estimate includes all material, labor and engineering necessary to construct a portable (skid-mounted) pilot plant to provide for the chemical treatment of explosive contaminated soil with a production capability of 2 tons/hour.

Cost Sources:
=============
TVA COST FILES
RRS '88
PRICE QUOTES

ASSUMPTIONS USED FOR OPERATING ESTIMATE:
==

Engineer	$40,000 per year
Chemical Analyst	38,000 per year
Operator Supervisor	20,800 per year
Operator	16,600 per year
Equip. Opr./Driver	16,600 per year
Maintenance	22,000 per year
Office Personnel	12,000 per year
Contingency	NONE
Fringe Benefits On Salary	40%
Hours Worked Per Year	2,080

CONSTRUCTION LABOR RATES:
=========================
From RRS (Jan.'89) - national average (includes fringe benefits)

Insulator	$23.20 per hour
Boilermaker	23.25 per hour
Carpenter	21.30 per hour
Concrete Finisher	19.60 per hour
Electrician	23.40 per hour
Iron Worker	23.10 per hour
Laborer	16.75 per hour
Millwright	21.80 per hour
Equipment Operator	21.95 per hour
Oiler	17.60 per hour
Painter	18.80 per hour
Pipefitter	23.90 per hour
Sheetmetal Worker	22.80 per hour

SUMMARY SHEET
****

Estimate No. 3755 | Work Order No. D01ATD

Project: USATHAMA - PROCESS FOR CHEMICAL TREATMENT OF EXPLOSIVE CONTAMINATED SOIL (W/ PACK. BOILER & AIR COMP.)

Prepared by: L. BISHOP
Cost by: L. BISHOP
Date Prepared: 1/4/89

DESCRIPTION	MAJOR MAT'L & EQUIPT	LABOR	CONTRACT	TOTAL
Site Preparation				
Foundations				
Building				
Process Equipment	422,792	28,166		450,958
Nonprocess Equipment	22,594	3,931	12,526	39,051
Equip Support and Str	15,467	67,290		82,757
Chutes and Ducts	1,200	4,104		5,304
Piping	14,124	27,772		41,896
Electrical	18,281	23,072		41,353
Instrumentation	57,875	16,988		74,863
Painting	1,000	3,824		4,824
Equipment Insulation	4,242	10,416		14,658
Pipe Insulation	2,200	3,999		6,199
Miscellaneous				
Total Direct Cost	$559,775	$189,564	$12,526	$761,864

Construction Expenses ..(34% of Process Equipment)........... 143,749

Engineering.............(30% of Process Equipment)........... 126,838

Startup and Test........(2% of Total Direct Cost)............ 15,237

Total Direct and Indirect Costs...................... $1,047,688

Contractors Fee.........(5% of Total Direct & Indirect Costs) 52,384

Budget Total...................................... $1,100,072

TOTAL PROJECT COST $1,100,072

SUMMARY
OPERATING COST

(ESTIMATE #3755)

(OPERATING COST BASED ON 1989 DOLLARS)

		PER 7 DAY WEEK	* ANNUAL COST/TON
1.	PERSONNEL	$10,618.46	$31.60
2.	OFFICE EXPENSE	25.00	0.07
3.	EQUIPMENT	193.73	0.58
4.	PILOT PLANT SUPPLIES	87.50	0.26
5.	RAW MATERIALS	11,239.20	33.45
6.	PILOT PLANT UTILITIES	6,098.00	18.15
7.	RECLAMATION COST	147.84	0.44
	TOTAL OPERATING COST PER 7 DAY WEEK.............	$28,409.73	* ANNUAL COST/TON $84.55

ADDITIONAL COST PER SITE

8. DISMANTLE, SHIPPING & REASSEMBLE
COST PER SITE.................. $19,537.00

* Annual cost/ton based on production capability of 2 tons/hour 24 hours/day, 7 days/week, 52 weeks/year. (17,472 tons/year)

OPERATING COST

(ESTIMATE #3755)

		PER 7 DAY WEEK
1. PERSONNEL:		
a. (ONE ENGINEER- 40 hours/week) ($40,000/2080*1.4*8*5)	=	$1,076.92
b. (CHEMICAL ANALYST- 40 hours/week) ($38,000/2080*1.4*8*5)	=	1,023.08
c. (OPERATORS- 4/shift; 4 shifts around the clock)		
ONE "A" OPERATOR ($20,800/2080*1.4*8*5*4)	=	2,240.00
TWO "B" OPERATORS ($16,600/2080*1.4*8*5*4*2)	=	3,575.38
ONE FRONT END LDR./TRK. DRIVER ($16,600/2080*1.4*8*5*4)	=	1,787.69
d. (MAINTENANCE- Monday thru Friday: Day Only: 1 Man) ($22,000/2080*1.4*8*5)	=	592.31
e. (OFFICE PERSONNEL 1 SECRETARY- 40 hours/week) ($12,000/2080*1.4*8*5)	=	323.08
	TOTAL....	10,618.46
2. OFFICE EXPENSE: (telephone $12.50, supplies $12.50)	=	25.00
	TOTAL...	25.00
3. EQUIPMENT:		
1 Front End Loader	=	59.54
1 Dump Truck	=	134.19
	TOTAL....	193.73
4. PILOT PLANT SUPPLIES: Gloves, boots, hardhats, safety glasses, data logging supplies, spare parts ($12.50/day*7)	=	87.5
	TOTAL	87.5

5.	RAW MATERIALS:		
	a. Caustic (48 lbs./hour @ 50%) (48*24*7*$0.1375)	=	$1,108.80
	b. Peroxide (134 lbs./hour - 70% industrial grade solution) (134*24*7*$0.45)	=	10,130.40
			=========
		TOTAL...	11,239.20
6.	PILOT PLANT UTILITIES:		
	a. Electricity (boiler, pump motors, agitators, air compressor, centrifuge and security lights) (600*24*$0.06*7)	=	$6,048.00
	b. Water	=	50.00
			=========
		TOTAL....	6,098.00
7.	RECLAMATION COST: ($0.44/ton) (2 tons/hr.*24*7*$0.44)	=	$147.84
			=========
		TOTAL...	147.84

APPENDIX B

COST ESTIMATION DETAILS FOR THE TRANSPORTABLE PROCESS DESIGN OPTIONS

B.1 Cost Estimation Methods

The capital and operating cost analysis methods for each transportable process option that was investigated are presented in this appendix. It includes costs for process system design, purchase of equipment and materials, installation of all equipment, and materials to produce an operable unit. Also included is the cost of personnel, raw materials, and utilities to operate the system to process a total of 300,000 tons of contaminated soil. Each plant is designed for a nominal eight-ton-per-hour average operating rate and was calculated to be relocated two times with complete site cleanup after relocation. Details of how operating costs were calculated are shown in Tables B-1 through B-6.

These estimates are based on flow diagrams, heat and material balance sheets, and other specifications contained in this report. In general, the following methods were used and the following assumptions were made in developing both the capital costs and operating costs for each process.

All construction labor rates were assumed to be those as published by Richardson Engineering Services, Inc. These rates are 1989 national averages, union scale, including fringe benefits for each craft assigned to do their portion of the construction.

B.1.1 Process Equipment

The capital cost for each piece of process equipment was obtained from recent TVA contracts and/or purchase requisitions, from TVA cost files for similar equipment, from telephone and/or written quotations from vendors, and from manufacturer's catalog information and price sheets.

Process equipment was sized and materials of construction were determined from process flow diagrams (PFDs) and accepted engineering practices. When necessary to obtain costs for various sizes of similar-capacity equipment, cost ratio exponents were used as published in Perry's Chemical Engineering Handbook, sixth edition.

Process equipment installation was estimated at 39 percent of equipment cost as suggested by Peters and Timmerhaus in Plant Design and Economics for Chemical Engineers, third edition.

B.1.2 Structures and Foundations

Exposed steel structures and equipment supports were estimated using a computer program which estimates an amount of structural steel and installation man-hours required based on cost of each piece of process equipment. Not included in steel costs are costs for finish painting and marking. These costs are included in Section B.1.6 (Miscellaneous).

B.1.3 Electrical and Instrumentation

All electrical and instrumentation costs include both labor man-hours and material costs to provide complete electrical and instrumentation services within the process area only. These costs are based on process equipment costs and do not include electrical services to plant facility, substation, area lighting outside process area, or telephone services. These latter electrical service costs as described in Section B.1.5 (Services and Utilities) are included in Section B.1.11 (Facilities Expense).

B.1.4 Process Piping

Process piping estimates were also made with a computer program using the process equipment cost as a basis for all piping costs. A line-by line estimate for piping costs was not practical because the chemical treatment process designs are not sufficiently detailed. However, after comparison of these costs with similar projects where detailed piping costs were made, the piping costs fell within an acceptable range. It was assumed that materials of construction and service would be similar to the materials of construction and service of the vessel(s) served by individual piping runs.

B.1.5 Services and Utilities

This section accounts for all services and utilities to the battery limits of the process area. The following assumptions were made to determine costs for these services:

1. Process Water.

   Sized according to requirements for each process, cast iron pipe, mechanical joint, buried in trench, 3,000 linear feet, installed.

   - Option A (Section 4.2.1) 6" $81,100
   - Option C (Section 4.2.3) 8" $98,600
   - Option F (Section 4.2.6) 8" $98,600

2. Electrical Transmission and Substation.

   A 12 KV overhead electrical transmission line, 3,000 feet long, is included in each system estimate. Also included is a 13 KV/480V distribution substation at the process plant site.

3. Telephone Line to Plant Facility.

An allowance of $5,000 was included in each estimate to provide commercial telephone service. An assumed distance to connect to existing system was 3,000 linear feet.

B.1.6 Miscellaneous Costs

Included in this section are costs for insulation for pipe and equipment for heat conservation and/or personnel protection and for painting of process equipment where required, steel structure, and piping systems. Painting is used for identification and corrosion protection.

B.1.7 Indirect Expenses

As recommended by Peters and Timmerhaus, the following percentages of process equipment were used to allow for other indirect expenses not directly accounted for in previous costs:

1. Engineering and supervision - 35%
2. Construction expense - 34%
3. Startup and testing - 2%*

* Startup and testing based on total direct expense.

B.1.8 Contractor's Fee

A six-percent allowance has been included for contractor's fee.

Also included in each capital cost estimate is a 15-percent contingency.

B.1.9 Operating Cost

Operating costs were assigned to each process using the following assumptions:

1. **Personnel**

Personnel	Number Required
Plant Engineer	1
Chemical Analyst	1
Laboratory Analyst	
Option A (4.2.1)	2
Option C (4.2.3)	2
Option F (4.2.6)	1
Operators:	
Option A (4.2.1)	3/shift
Option C (4.2.3)	4/shift
Option F (4.2.6)	6/shift
Maintenance: (day shift only)	
Option A (4.2.1)	2
Option C (4.2.3)	4
Option F (4.2.6)	3
Office Personnel	1

2. **Office Expense**

Office expense includes normal telephone usage, office supplies, paper, etc.

3. **Pilot Plant Supplies**

Pilot plant supplies include expendable items used by operators such as gloves, boots, safety glasses, hard hats, spare parts, data logging supplies, etc.

4. Raw Materials

Raw materials for Option A (Section 4.2.1) and Option C (Section 4.2.3) include caustic at 50-percent solution and peroxide in 70-percent, industrial-grade solution.

5. Pilot Plant Utilities

Major utilities include use of electricity, water, and propane during normal operation of the plant.

B.1.10 Relocation Expense

This portion of the estimate is based on the plant being disassembled and reusable components being shipped to a new site and reconstructed. New materials will be purchased and installed as required (concrete, insulation, etc.). The remaining portions of the plant not reusable at a new site will be removed and disposed of as required to return the site to its former condition. This estimate does not take any credit for material or equipment that may be sold to recover partial cost. Transportation costs were calculated on maximum of 500 miles per relocation.

Indirect cost for second and third sites were calculated as shown in Sections B.1.7 and B.1.8 as follows:

1. Engineering and supervision - 17.5%
2. Construction Expense - 34.0%
3. Startup and Testing - 2.0%
4. Contractors Fee - 4.2%
5. Contingency - 5.0%

This section contains the costs for installing an office complex (trailers) and other related costs to establish a usable processing plant site. Costs were assumed not to vary from site to site and generally include the following:

	Item	Cost
1.	Office trailer, furnished, w/HVAC	$ 20,400
2.	Laboratory trailer, w/lab equipment, HVAC	29,400
3.	Break and lunch trailer, furnished, w/HVAC	19,400
4.	Change room trailer, w/showers, HVAC	70,400
5.	Site clearing	27,300
6.	Gravel for roads and parking	9,600
7.	Sidewalks	13,200
8.	Chain-link fencing	72,600
9.	Outdoor lighting system	80,000
10.	Sewer system (septic tank)	5,000
11.	Truck scales	50,000
12.	Telephone service	5,000
13.	Electrical substation and transmission	100,000[1]
14.	Water line	98,600[2]

[1] $125,000 for Option C.

[2] $81,100 for Option A.

Where possible, equipment and materials (trailers, outdoor lighting, fencing, scales, etc.) will be relocated to the new site and reused. Other materials and services will be removed or plugged and left in plant below grade. All sites will be cleaned and left in an environmentally acceptable condition when processing plant is moved to a new location. Those costs are included both in this section and in Section B.1.10.

TABLE B-1

FRONT END/TRUCK SOLID FEED SOIL HANDLING COST

	WEEKLY COST
1. PERSONNEL:	
A. EQUIPMENT OPERATORS- 6/shift; 4 shifts	
LOADING AT POND Loader Operator Truck Driver ($16,600/2080*1.4*8*5*8)	$3,575.38
LOADING AT PLANT Loader Operator ($16,600/2080*1.4*8*5*4)	1,787.69
HAULING SPOIL TO FILL Loader Operator 2 Truck Drivers ($16,600/2080*1.4*8*5*12)	5,363.08
MAINTENANCE- Monday thru Friday: Day Only: 1 Man ($22,000/2080*1.4*8*5*1)	592.31
Subtotal: Personnel Expense	$11,318.46
2. EQUIPMENT OPERATING EXPENSE:	
Fuel and Oil	
Front end loader - $20/day	$420.00
Dump truck - $25/day	525.00
Subtotal: Operating Expense	$945.00
3. EQUIPMENT EXPENSE:	
3 Front End Loaders @$70,000	$210,000.00
3 Dump Trucks @$35,000	105,000.00
Subtotal: Equipment Expense	$315,000.00

TABLE B-2

ON-SITE SLURRY PIPELINE/PUMP SOIL HANDLING COST

	WEEKLY COST
1. PIPELINE FOR TRANSPORT OF SLURRY: Assume 3,000 LF pumping distance-	
AT POND Loader Operator ($16,600/2080*1.4*8*5*4)	$1,787.69
AT PLANT Operator ($16,600/2080*1.4*8*5*4)	1,787.69
HAULING SPOIL TO FILL Loader Operator 2 Truck Drivers ($16,600/2080*1.4*8*5*12)	5,363.08
MAINTENANCE- Monday thru Friday: Day Only: 1 Man ($22,000/2080*1.4*8*5*1)	592.31
Subtotal: Personnel Expense	$9,530.77
2. EQUIPMENT OPERATING EXPENSE:	
Fuel and Oil	
Front end loader - $20/day	$280.00
Dump truck - $25/day	350.00
Subtotal: Operating Expense	$630.00
3. EQUIPMENT EXPENSE:	
2 Front End Loaders @$70,000	$140,000.00
2 Dump Trucks @$35,000	70,000.00
Slurry Mix Tank & Agitator	14,400.00
4-30 HP, 400gpm Pumps, installed	46,600.00
6,000 LF, 6" Pipe, CS, installed	197,000.00
Subtotal: Equipment Expense	$468,000.00

TABLE B-3

CONVEYOR SYSTEM SOLID FEED
SOIL HANDLING COST

	WEEKLY COST
1. CONVEYOR FOR TRANSPORT-PERSONNEL Assume 3,000 LF conveyor distance	
AT POND Loader Operator ($16,600/2080*1.4*8*5*4)	$1,787.69
AT PLANT Operator ($16,600/2080*1.4*8*5*4)	1,787.69
HAULING SPOIL TO FILL Loader Operator 2 Truck Drivers ($16,600/2080*1.4*8*5*12)	5,363.08
MAINTENANCE- Monday thru Friday: Day Only: 1 Man ($22,000/2080*1.4*8*5*1)	592.31
Subtotal: Personnel Expense	$9,530.77
2. EQUIPMENT OPERATING EXPENSE: Fuel and Oil	
Front end loader - $20/day	$280.00
Dump truck - $25/day	350.00
Subtotal: Operating Expense	$630.00
3. EQUIPMENT EXPENSE:	
2 Front End Loaders @$70,000	$140,000.00
2 Dump Trucks @$35,000	70,000.00
Hopper with viberating eeder	16,500.00
3-1000',24" wide, covered conveyors	636,600.00
Subtotal: Equipment Expense	$863,100.00

TABLE B-4

OPERATING COSTS
8 TPH HYDROLYSIS/OXIDATION
DEGRADATION SYSTEM

		WEEKLY COST
1.	PERSONNEL:	
	a. ONE ENGINEER- 40 hours/week ($40,000/2080*1.4*8*5)	$1,076.92
	b. CHEMICAL ANALYST- 40 hours/week ($32,000/2080*1.4*8*5)	861.54
	c. LABORATORY ANALYST- 40 hours/week ($24,000/2080*1.4*8*5*2)	1,292.31
	c. OPERATORS- 3/shift; 4 shifts	
	ONE "A" OPERATOR ($20,800/2080*1.4*8*5*4)	2,240.00
	TWO "B" OPERATORS ($16,600/2080*1.4*8*5*4*2)	3,575.38
	d. MAINTENANCE- Monday thru Friday: Days Only: 2 Men ($22,000/2080*1.4*8*5*2)	1,184.62
	e. OFFICE PERSONNEL 1 SECRETARY- 40 hours/week ($12,000/2080*1.4*8*5)	323.08
	Subtotal Personnel	$10,553.85
2.	OFFICE EXPENSE: telephone $12.50 supplies $12.50	$25.00
	Subtotal: Office Expense	$25.00
3.	PILOT PLANT SUPPLIES: Gloves, boots, hardhats, safety glasses, data logging supplies, spare parts ($12.50/day*7)	$87.50
	Subtotal Plant Supplies	$87.50

TABLE B-4 (Continued)

OPERATING COSTS
8 TPH HYDROLYSIS/OXIDATION
DEGRADATION SYSTEM

4.	RAW MATERIALS:	
	a. Caustic (246 lbs./hour @ 50%) (246*24*7*$0.1375)	$5,682.60
	b. Peroxide (746 lbs./hour- 70% industrial grade solution) (746*24*7*$0.475)	59,530.80
	Subtotal Raw Materials	$65,213.40
5.	PILOT PLANT UTILITIES:	
	a. Electricity (pump motors, agitators, air compressor, centrifuge and security lights) (1200*24*$0.06*7)	$12,096.00
	b. Water (2000GPM)	309.12
	c. Propane (Boiler)	9,198.00
	Subtotal Utilities	$21,603.12

TABLE B-5

OPERATING COSTS
8 TPH MICROWAVE/OXIDATION
DEGRADATION SYSTEM

		WEEKLY COSTS
1.	PERSONNEL:	
	a. ONE ENGINEER- 40 hours/week ($40,000/2080*1.4*8*5)	$1,076.92
	b. CHEMICAL ANALYST- 40 hours/week ($32,000/2080*1.4*8*5)	861.54
	c. LABORATORY ANALYST- 40 hours/week ($24,000/2080*1.4*8*5*2)	1,292.31
	c. OPERATORS- 4/shift; 4 shifts	
	ONE "A" OPERATOR ($20,800/2080*1.4*8*5*4)	2,240.00
	THREE "B" OPERATORS ($16,600/2080*1.4*8*5*4*3)	5,363.08
	d. MAINTENANCE- Monday thru Friday: Day Only: 4 Men ($22,000/2080*1.4*8*5*4)	2,369.23
	e. OFFICE PERSONNEL 1 SECRETARY- 40 hours/week ($12,000/2080*1.4*8*5)	323.08
	Subtotal Personnel	$13,526.15
2.	OFFICE EXPENSE: telephone $12.50 supplies $12.50	$25.00
	Subtotal: Office Expense	$25.00
3.	PILOT PLANT SUPPLIES: Gloves, boots, hardhats, safety glasses, data logging supplies, spare parts ($12.50/day*7)	$87.50
	Subtotal Plant Supplies	$87.50

TABLE B-5 (Continued)

OPERATING COSTS
8 TPH MICROWAVE/OXIDATION
DEGRADATION SYSTEM

4. RAW MATERIALS:	
a. Caustic (246 lbs./hour @ 50%) (246*24*7*$0.1375)	$5,682.60
b. Peroxide (373 lbs./hour-70% industrial grade solution) (373*24*7*$0.475)	29,765.40
Subtotal Raw Materials	$35,448.00
5. PILOT PLANT UTILITIES:	
a. Electricity (pump motors, microwaves, agitators, air compressor, centrifuge and security lights) (2,200*24*$0.06*7)	$12,096.00
b. Water (4,500 gpm)	686.40
Subtotal Utilities	$12,782.40

TABLE B-6

OPERATING COST ESTIMATE
8 TPH SFC/OXIDATION
DEGRADATION SYSTEM

	WEEKLY COST
1. PERSONNEL:	
a. ONE ENGINEER- 40 hours/week ($40,000/2080*1.4*8*5)	$1,076.92
b. CHEMICAL ANALYST- 40 hours/week ($32,000/2080*1.4*8*5)	861.54
c. LABORATORY ANALYST- 40 hours/week ($24,000/2080*1.4*8*5)	646.15
c. OPERATORS- 6/shift; 4 shifts	
ONE "A" OPERATOR ($20,800/2080*1.4*8*5*4)	2,240.00
FIVE "B" OPERATORS ($16,600/2080*1.4*8*5*4*5)	8,938.46
d. MAINTENANCE- Monday thru Friday: Day Only: 3 Men ($22,000/2080*1.4*8*5*3)	1,776.92
e. OFFICE PERSONNEL 1 SECRETARY- 40 hours/week ($12,000/2080*1.4*8*5)	323.08
Subtotal Personnel	$15,863.08
2. OFFICE EXPENSE: telephone $12.50 supplies $12.50	$25.00
Subtotal: Office Expense	$25.00
3. PILOT PLANT SUPPLIES: Gloves, boots, hardhats, safety glasses, data logging supplies, spare parts ($17.50/day*7)	$122.50
Subtotal Plant Supplies	$122.50

TABLE B-6 (Continued)

OPERATING COST ESTIMATE
8 TPH SFC/OXIDATION
DEGRADATION SYSTEM

4.	RAW MATERIALS: No raw materials required	
	Subtotal Raw Materials	$0.00
5.	PILOT PLANT UTILITIES:	
	a. Electricity (pump motors, agitators, air compressor, and security lights) (600*24*$0.06*7)	$6,048.00
	b. Water (5,000 GPM)	772.80
	c. Propane (Boiler)	54,306.00
	Subtotal Utilities	$61,126.80

EXPLOSIVE LAGOON SEDIMENT CHARACTERIZATION
AND RECLAMATION AFTER CHEMICAL OXIDATION

ECONOMIC ANALYSIS
Frank J. Sikora

An economic analysis of reclaiming the TNT-lagoon soil after chemical oxidation has been conducted. The analysis assumes amendments of straw and fly ash will be needed to improve the chemical and physical characteristics of the soil. The amendments, fertilizer, and seed requirements are taken from research information obtained on reclamation of surface mined land in the Eastern United States (ref).

Item	application rate ---tons/acre---	cost --$/ton--	acreage cost ---$/acre-----
straw	1.5	$180	$270
fly ash	150	transportation cost	
fertilizer	0.5	$150	$75
seed	0.023		
49% Kentucky 31 fescue	0.0113	$2100	$24
23% Orchard grass	0.0053	$2400	$13
28% Rye grass	0.0064	$1800	$12

based on $2.25/bale and assuming 1 bale=25 lbs.

The above table lists material costs. There is some cost associated with application of the materials (eg. tractor costs, manpower, etc.) which has not been determined.